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LENS ARRAY PACKAGE AND FABRICATION
METHOD

BACKGROUND

[0001] The invention relates generally to lens array packaging.

[0002] Many optoelectronic applications require lens arrays to either collimate or focus optical beams. Such systems typically include about four to forty eight optical paths. Alignment of all of the optical paths is typically needed between the lens array and one or more of a fiber array, a detector array, and an emitter array. Conventional alignment techniques for lenses and fibers use manual and automated active alignment processes wherein an optical path is illuminated and a detector is used to monitor the optical path during the alignment process. Active alignment processes are time consuming and hinder efforts to bring down the expense associated multi-path optoelectronic modules.

[0003] It would therefore be desirable to provide a lens array package without using a labor intensive alignment process.

BRIEF DESCRIPTION

[0004] Briefly, in accordance with one embodiment of the present invention, a method comprises attaching a lens array to a package substrate with lenses of the lens array situated opposite the package substrate, surrounding a periphery of the lens array with a packaging material, the packaging material being attached to the package substrate, planarizing the packaging material, the planarized packaging material having a height higher than a height of the lens array, and providing alignment holes through the packaging material, the alignment holes being aligned with respect to positions of the lenses.

[0005] In accordance with another embodiment of the present invention, a structure comprises a substantially transparent package substrate, a lens array attached

to the package substrate with lenses of the lens array situated opposite the package substrate, and packaging material surrounding at least the periphery of the lens array, the packaging material including at least two alignment holes which are aligned with respect to positions of the lenses and having a height higher than a height of the lens array.

DRAWINGS

[0006] These and other features, aspects, and advantages of the present invention will become better understood when the following detailed description is read with reference to the accompanying drawings in which like characters represent like parts throughout the drawings, wherein:

[0007] FIGs. 1-6 are sectional side view of stages in a lens package fabrication process in accordance with one embodiment of the present invention.

[0008] FIG. 7 is a top view of a stage in a lens package fabrication process in accordance with another embodiment of the present invention.

[0009] FIG. 8 is a sectional side view of a stage in a lens package fabrication process in accordance with another embodiment of the present invention.

[0010] FIG. 9 is a sectional side view of a lens package fabricated by the embodiment of FIGs. 1-6.

[0011] FIG. 10 is a sectional side view of the lens package of FIG. 9 coupled with an optical module comprising a fiber module.

[0012] FIG. 11 is a sectional side view of the lens package of FIG. 9 coupled with an optical module comprising a photonic module.

[0013] FIG. 12 is a sectional side view of the assembly of FIG. 10 coupled to the assembly of FIG. 11.

DETAILED DESCRIPTION

[0014] FIGs. 1-6 are sectional side view of stages in a lens package fabrication process in accordance with one embodiment of the present invention wherein a method comprises attaching a lens array 10 (meaning at least one lens array) to a package substrate 16 with lenses 12 of lens array 10 situated opposite package substrate 16 (FIG. 1); surrounding a periphery of lens array 10 with a packaging material 54 (FIGs. 4-6), packaging material 54 being attached to package substrate 16 (FIGs. 2-4); planarizing packaging material 54 (FIG. 4), the planarized packaging material 54 having a height higher than a height of the lens array; and providing alignment holes 32 through packaging material 54 (FIG. 5), the alignment holes being aligned with respect to positions of the lenses.

[0015] Lens array 10 typically comprises a lens array substrate 14 comprising a substantially transparent material such as glass, and lenses 12 comprising microlenses with one example diameter being 250 micrometers. As used herein “substantially transparent” means absorbing less than about thirty percent of the incident light.

[0016] Package substrate 16 typically comprises any structurally suitable substantially transparent material. In one embodiment, package substrate 16 comprises a polymer, and in a more specific embodiment, the polymer comprises a polyimide, a polyetherimide, or a liquid crystal polymer. In such embodiments, wherein package substrate 16 is flexible (as opposed to a rigid material such as glass), it is particularly useful to additionally attach packaging material 54 to lens array 10 (as shown in the example FIGs. 2-6) by at least touching enough of the periphery in order secure lens array 10 in position with respect to substrate 16.

Optional adhesive 18 is useful for attaching lens array 10 and package substrate 16. Adhesive 18 may comprise any substantially transparent conventional die attach adhesive and in one example comprises epoxy based photo-patternable dielectric material designed for spin coating thin films available from Shipley Electronics under the name XP9500, for example.

[0017] Planarizing is typically accomplished using mechanical milling or lapping, for example. In FIG. 4, element 30 is used to show the distance between the top of lens 12 and planarized surface 28. In one embodiment distance 30 is about 600 micrometers. Planarizing can be facilitated by use of stop blocks 20. In one embodiment, stop blocks 20 comprise aluminum oxide (Al_2O_3) and have heights of about 1 millimeter. "Planarizing," as used herein, does not mean that the surface need be perfectly planar. Surface 28 is generally parallel to package substrate with less than about 10 micrometers of total run out across the lens array.

[0018] Typically two alignment holes 32 are provided for each lens array 10. However, additional alignment holes 32 can be added if desired. Positions of alignment holes 32 can be selected using features on lens array 10 for accurate positioning of alignment holes 32 with respect to lenses 12. Alignment holes 32 provide for the mechanical alignment of lens array 10 with either a conventional MT optical connector or an optical module provided with similar alignment holes.

[0019] In one embodiment, alignment holes 32 are fabricated using drilling. One example of a useful laser for drilling is an ultraviolet laser such as model 5200 from Electro Scientific Industries. Advantageously the two holes can be drilled to coincide with the interface of the optical module to be attached. For MT connectors, the spacing between pins is 4.6 millimeters, for example.

[0020] Although the embodiment of FIGs. 1-6 illustrates a single lens array, large numbers of lens arrays can be packaged simultaneously. For each lens array, one side of the lens array is protected by substrate 16 and the other side is protected by being recessed into the back of the resulting lens package 36. The spacing from the back of the lens is set by the planarization step thereby simplifying the optical assembly.

[0021] In the embodiment illustrated in FIGs. 1-6, packaging material 54 comprises a first dam 22 around the periphery of the lens array, a second dam 24 around first dam 22, and filler material 26 between the first and second dams. In embodiments wherein adhesive 18 is used, it is useful to cure adhesive 18 prior to forming any dams. After the dam and fill operations, first and second dams 22 and 24

and filler material 26 are typically cured in a temperature controlled chamber (prior to planarizing). Stop blocks 20 may optionally be used in this embodiment as well. If stop blocks 20 are used, the heights of first and second dams 22 and 24 and filler material 26 are greater than the height of stop blocks 20. In any embodiment, an advantage of stop blocks is that stop blocks provide a simple mechanism for controlling the height of packaging material 54 during planarization.

[0022] Material of first and second dams 22 and 24 typically comprises a polymer but may comprise any material that can be applied in a manner to bead in the desired pattern for creating a dam. In a more specific embodiment, the dams comprise thixotropic material. In one process for forming first and second dams 22 and 24, an adhesive dispense machine (not shown) is used to “draw” the dams. More specific examples of useful dams and filler materials include epoxy resins with fillers to affect flow, shrinkage, and coefficient of thermal expansion. Several even more specific epoxy examples are Loctite HYSOL FP4451-TD for dams and Loctite HYSOL FP4651 for filler material, both available from Henkel Technologies.

[0023] Although second dam 24 is shown in proximity to first dam 22 in FIGs. 2-6 for purposes of illustration, second dam need not be in any specific location. For example, FIG. 7 is a top view of a stage in a lens package fabrication process in accordance with another embodiment of the present invention wherein second dam 124 is situated toward the outer edge of substrate 16. The embodiment of FIG. 7 is useful because one second dam 124 can be used in combination with multiple lens arrays 110 and 210 and multiple first dams 122 and 222.

[0024] FIG. 8 is a sectional side view of a stage in a lens package fabrication process in accordance with another embodiment of the present invention wherein packaging material 54 comprises a dam 322. In embodiments wherein a single dam is used without filler material, dam 322 needs sufficient dimensions to provide space for alignment holes 232.

[0025] FIG. 9 is a sectional side view of a lens package 36 fabricated by the embodiment of FIGs. 1-6 after the package substrate has been cut to form lens

package 36 (along singulation cuts 34 of FIG. 6, for example) comprising lens array 10, a remaining portion of packaging material 54 (element 54 shown in FIG. 4), and alignment holes 32.

[0026] FIG. 10 is a sectional side view of the lens package of FIG. 9 coupled with an optical module comprising a fiber 44 module 38. In one embodiment, lens package 10 and optical module 38 are mechanically coupled by inserting pins 40 through the alignment holes. Pins 40 may be attached to one of lens package 10 and optical module 38 either prior to or after positioning the lens package adjacent the optical module.

[0027] FIG. 11 is a sectional side view of the lens package of FIG. 9 coupled with an optical module comprising a photonic module 46. In one embodiment, photonic module 46 is similar to the module described in Kryzak et al., US Patent No. 6,322,257 which describes incorporation of an interconnect layer 48 comprising multiple dielectric and electrical interconnection layers (not shown) with the electrical interconnection layers not overlying optically active portions of the module. As shown in FIG. 11, typical elements of a photonic module are photonic die 52 and a heat spreader 50 encased in a module substrate 42. Photonic die 52 typically includes photonic die elements 58 which may comprise emitters (such as vertical cavity surface emitting laser) or detectors (such as photodiodes), for example.

[0028] FIG. 12 is a sectional side view of the assembly of FIG. 10 coupled to the assembly of FIG. 11. More specifically, in this embodiment, lens package 36 comprises a first lens package 136 and optical module 38 comprises a first optical module 138 and first lens package 136, a second lens package 236, first optical module 138, and a second optical module 146 are mechanically coupled by pins 140 (illustrating one pin through each of the modules and packages or 240 (illustrating separate pins for separate modules). Although not shown, embodiments wherein the first and second modules both comprise fiber or photonic modules are also within the scope of the present invention.

[0029] Any of the optical modules in FIGs. 10-12 may comprise optical elements selected from the group consisting of, optical fibers, photo emitters, and photo detectors, and combinations thereof with at least some of the optical elements being aligned with respective lenses. In one more specific embodiment, at least one of the optical elements is situated at a distance of approximately one focal length from a respective lens (more specifically, from the edge of the lens facing away from package substrate 16). When working with small lenses, it can be difficult to accurately identify a precise focal point 56 or 58 (FIG. 12). As used herein, "approximately one focal length" means within about twenty percent of the distance where a collimated input beam width is minimized.

[0030] Using the above described embodiments, conventional microlens arrays can be aligned to conventional MT optical connectors and optical microelectromechanical systems (OMEMS) using semiconductor packaging materials and processes and a passive alignment technique (meaning that the optical elements do not have to be energized during fabrication). Packaging material 54 protects microlens array 10 and provides accurate spacing from lens to optical elements.

[0031] While only certain features of the invention have been illustrated and described herein, many modifications and changes will occur to those skilled in the art. It is, therefore, to be understood that the appended claims are intended to cover all such modifications and changes as fall within the true spirit of the invention.